Chapter 11

Ohio River Case Study

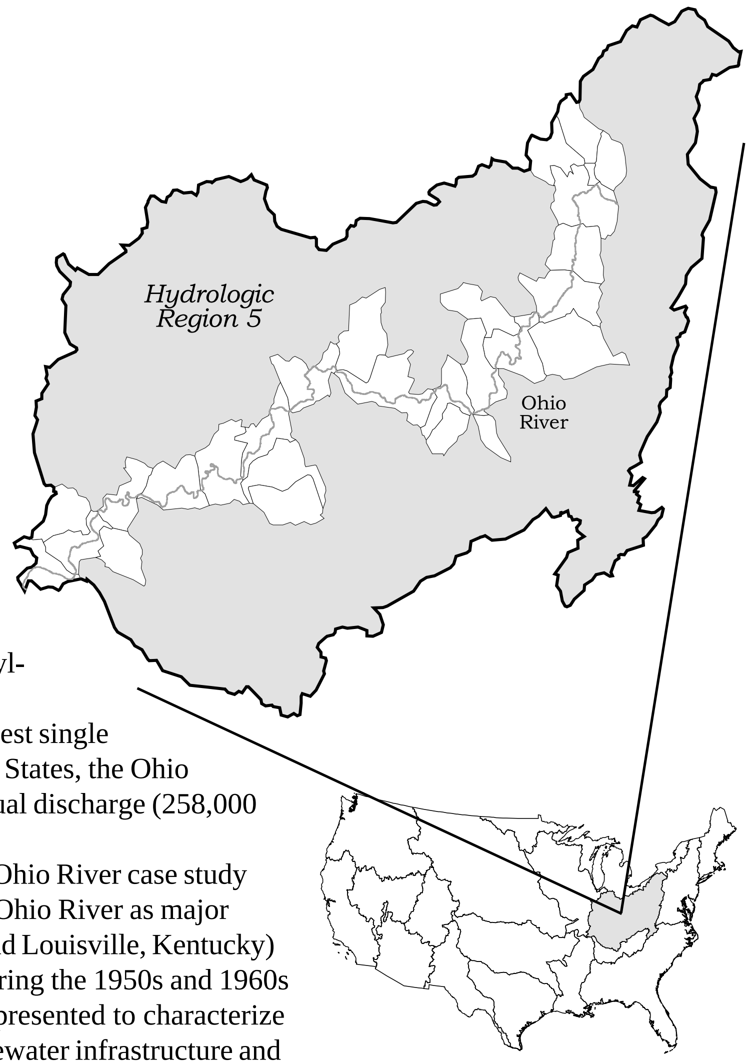


Figure 11-1

Hydrologic Region 5 and the Ohio River Basin.

The Ohio River Basin, covering a drainage area of 204,000 square miles, extends 1,306 miles from the headwaters of the Alleghany River in Potter County, Pennsylvania, to the confluence of the Ohio River with the Mississippi River at Cairo, Illinois. With a length of 981 miles from the confluence of the Alleghany and Monangahela rivers with the Ohio River at Pittsburgh, Pennsylvania, to Cairo, Illinois, and a drainage area of 192,200 square miles, the Ohio River is the largest single tributary to the Mississippi River. In the United States, the Ohio River ranks 10th in length and 3rd in mean annual discharge (258,000 cfs) (Iseri and Langbein, 1974).

Figure 11-1 highlights the location of the Ohio River case study watersheds (catalog units) identified along the Ohio River as major urban-industrial areas (e.g., Cincinnati, Ohio, and Louisville, Kentucky) affected by severe water pollution problems during the 1950s and 1960s (see Table 4-2). In this chapter, information is presented to characterize long-term trends in population, municipal wastewater infrastructure and effluent loading of pollutants, ambient water quality, environmental resources, and uses of the Ohio River. Data sources include USEPA's national water quality database (STORET), published technical literature, and unpublished technical reports ("grey" literature) obtained from the Ohio River Valley Sanitation Commission (ORSANCO) and other local agency sources.

The ORSANCO district encompasses three-quarters of the basin, accounting for 155,000 square miles of the Ohio River watershed. The district contains nearly one-tenth of the Nation's population in one-twentieth of the Nation's continental area. Ten percent of the people in the watershed receive their water supply from the Ohio River. Population densities in the ORSANCO district range from less than 50 people per square mile in the southwest to more than 600 in the eastern urban centers. Land use in the area is primarily agricultural, but concentrations of industry, coal mining, and oil and gas drilling are present throughout the region. In addition to agricultural and industrial uses, the Ohio River supports fish and wildlife habitats, water-based recreation, navigation, and power generation.

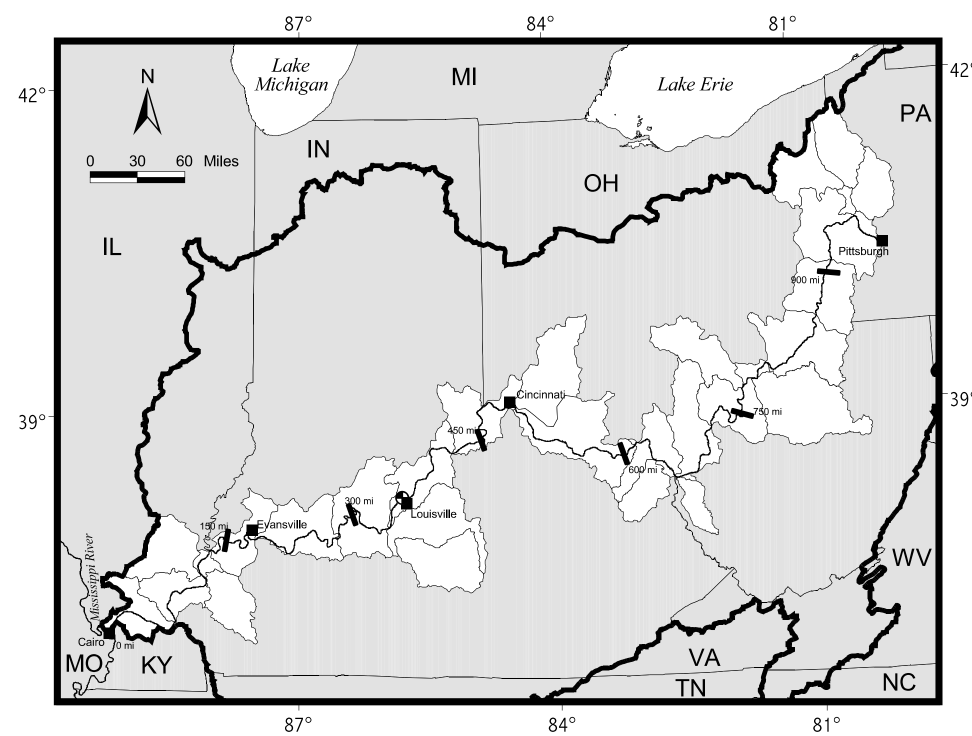
Utility of the Ohio River had significantly declined by the 1930s as the result of rising discharges of raw sewage and untreated industrial waste. Widespread public concern was spurred by drought-induced epidemics in 1930 and continually high levels of bacterial pollution. Citizens of the Ohio River Valley proposed a regional approach to water quality management in the form of an interstate compact. Eight states joined the Ohio River Valley Sanitation Commission in 1948, setting a precedent for cooperation among state, local, and private interests and the federal government for unifying waste management within individual watersheds. The benefits of pollution control standards implemented through this region-wide compact have been significant to the overall condition of waterways in the Ohio River Basin.

Physical Setting and Hydrology

Nineteen major tributaries discharge to the Ohio River (Figure 11-2). The 155,000-square-mile ORSANCO district originates on the western slopes of the Appalachian Mountains, with the Allegheny River flowing into the Ohio River from the northwest and the Monangahela River from the south. The southwestern portion of the district is characterized by rolling hills and wide valleys, and the northwest is level or gently rolling. The elevation of the Ohio's riverbed drops 429 feet from the headwaters to the mouth at the confluence with the Mississippi

Figure 11-2

Location of Upper, Middle, and Lower Ohio River watersheds. River miles shown are distances from confluence of Ohio River with Mississippi River at Cairo, Illinois.



River, with flow in the drainage basin generally toward the southwest. The ORSANCO district is approximately 700 miles long and has an average width of 220 miles. Rainfall in the basin averages 45 inches, and the average annual discharge of the Ohio River into the Mississippi River is 260,000 cfs. Variations in rainfall, temperature, vegetation coverage, and snow storage have historically caused wide ranges of runoff and streamflows. Low-flow conditions usually occur in July through November; the monthly average, taken at Louisville, Kentucky, ranges from 33,853 cfs in September to 239,613 cfs in March. Figures 11-3 and 11-4 show summer average flows (July-September) and monthly average flows over the 55-year period from 1940 to 1995.

Canalization of the entire Ohio River and some of its tributaries was achieved by 1929, converting the river into a series of backwater pools. The original system of submergible wicket dams has been almost completely replaced by high-lift permanent dams (Tennant, 1998).

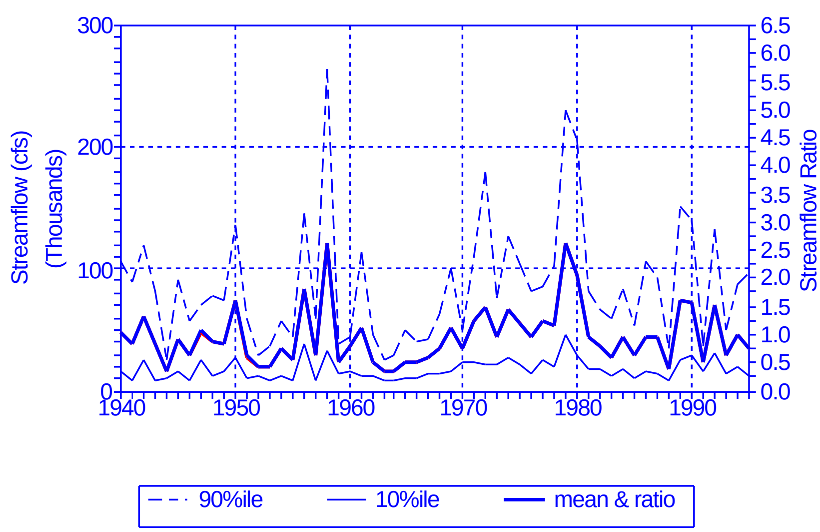


Figure 11-3

Long-term trends in mean, 10th, and 90th percentile statistics computed for summer (July-September) streamflow in the Ohio River. (USGS Gage 03294500 at Louisville, Kentucky.)

Source: USGS, 1999.

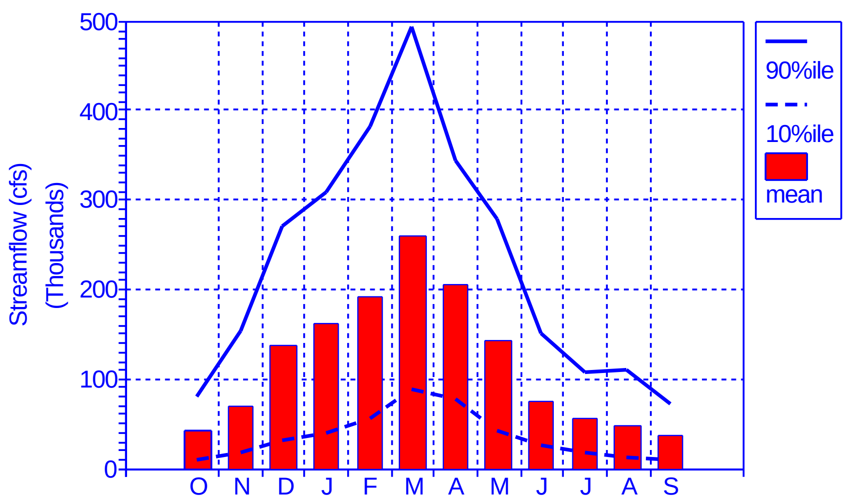


Figure 11-4

Monthly trends in streamflow for the Ohio River. Monthly mean, 10th, and 90th percentiles computed for 1951-1980. (USGS Gage 03294500 at Louisville, Kentucky.)

Source: USGS, 1999.

Population, Water, and Land Use Trends

The Ohio River Basin continues to be one of the most important agricultural and industrial centers of the Nation. Population in the ORSANCO district has increased steadily over the past few decades, and use of the water resources has increased with the development of the basin. More than 3,700 municipalities, more than 1,800 industries, and three major cities—Louisville, Cincinnati, and Pittsburgh—depend on the Ohio River Valley. The Ohio River case study area includes a number of counties identified by the Office of Management and Budget (OMB) as Metropolitan Statistical Areas (MSAs) or Primary Metropolitan Statistical Areas (PMSAs). Table 11-1 lists the MSAs and counties included in this case study. Figure 11-5 presents long-term population trends (1940-1996) for the counties listed in Table 11-1. From 1940 to 1996, the population in the Ohio

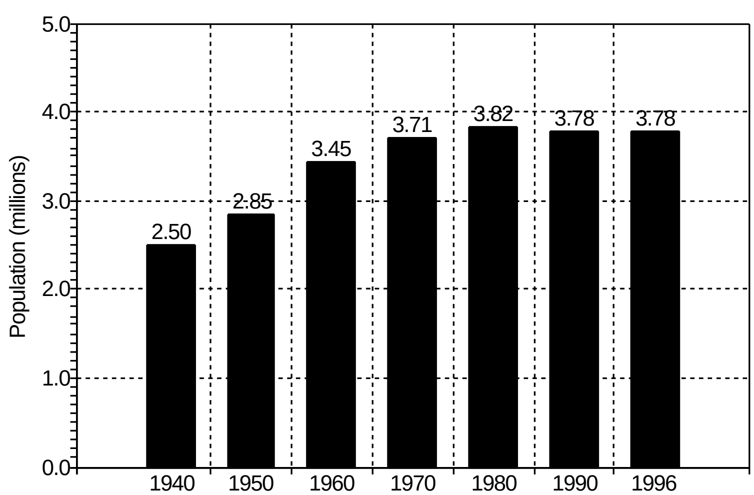
Table 11-1. Metropolitan Statistical Area (MSA) counties in the Ohio River Basin case study. *Source: OMB, 1999.*

Wheeling, WV-OH MSA	*Cincinnati-Hamilton, OH-KY-IN CMSA*	*Louisville, KY-IN MSA*
Belmont County, OH	Dearborn County, IN	Clark County, IN
Marshall County, WV	Ohio County, IN	Floyd County, IN
Ohio, WV	Boone County, KY	Harrison County, IN
Steubenville-Weirton, OH-WV MSA	Campbell County, KY	Scott County, IN
Jefferson County, OH	Kenton County, KY	Bullitt County, KY
Brooke County, WV	Pendleton County, KY	Jefferson County, KY
Huntington-Asland, WV-KY-OH MSA	Brown County, OH	Oldham County, KY
Boyd County, KY	Clermont County, OH	*Evansville-Henderson, IN-KY MSA*
Carter County, KY	Hamilton County, OH	Posey County, IN
Greenup County, KY	Warren County, OH	Vanderburgh County, IN
Lawrence County, OH	Butler County, OH	Warrick County, IN
Cabell County, WV		Henderson County, KY
Hancock County, WV		
Wayne County, WV		

Figure 11-5

Long-term trends in population in the Ohio River Basin.

Sources: Forstall, 1995; USDOC, 1998



River case study area increased by more than 50 percent (Forstall, 1995; USDOC, 1998). Agriculture continues to be the dominant land use in the area although extensive mining is conducted in the watershed; 70 to 80 percent of the national total amount of bituminous coal and a significant amount of natural gas and oil are present in the basin.

The Ohio River supports navigation, power generation, industrial cooling and processing, warm-water aquatic habitats, public water supplies, and recreation. Because the river serves as a water source to industries, agricultural lands, and more than 3.5 million people, and as a waste receptacle for far larger numbers, the river's environment has been placed in a fragile balance.

Historical Water Quality Issues

Growing concern for the deteriorating environmental conditions in the Ohio River peaked in the early 1930s when serious drought turned many slackwater pools into virtual cesspools and a series of epidemics plagued cities along the Ohio River. Costs of water treatment increased dramatically from 1921 to 1934 as a result of an estimated 80-fold increase in the bacteria levels present in the river. In 1936 Congressman Brent Spence testified at a congressional hearing on the pollution of navigable waters that "the Ohio River is a cesspool." At the same hearing the State Health Commissioner of Kentucky added that "the Ohio River, from Pittsburgh to Cairo, is an open sewer." In 1939 the city of Marietta, Ohio, was forced to change its water supply source from the Ohio River to wells and the Muskingum River as pollution levels in the river became untreatable. In 1951 only 39 percent of the sewered population was served by community treatment facilities. Sections of the Ohio River still suffered oxygen depletion so severe that aquatic life could not survive and pollution, bacteria levels, taste, and odor made large sections of the Ohio River unsuitable for most uses.

Legislative and Regulatory History

Large-scale action was delayed by the need for cooperation throughout the basin to achieve significant improvements in water quality. In 1908 the Ohio state legislature adopted the Bense Act which, exempted every Ohio village and municipality from installing sewage treatment works until similar facilities were provided by all municipalities upstream from it. This attitude endured until 1924 when the Ohio River Valley Negotiating Committee reported an agreement between industries and state health commissioners to cooperate in carrying out a policy for the conservation of interstate streams. Congress authorized the states to negotiate the compact in 1936 and approved the resulting document in 1940. In June of 1948 the Federal Water Pollution Control Act (Public Law 80-845) was passed and the ORSANCO Compact was signed by Illinois, Indiana, Kentucky, New York, Ohio, Pennsylvania, Virginia, and West Virginia, setting a precedent for cooperation among federal agencies, state governments, municipalities, and industries. Soon after, wastewater treatment standards were enacted for the Cincinnati pool. Bacterial quality objectives for the Ohio River were established in 1951, and an assessment of potential health hazards from trace constituents in wastewaters was initiated. By 1954 municipal wastewater treatment standards for the Ohio River had been established. In relation to the industrial dischargers, a resolution adopted in 1959 placed responsibility on industries for reporting spills and accidental discharges to state agencies.

Following the 1965 Federal Water Quality Act, ORSANCO adopted stream water quality recommendations. In 1970 ORSANCO Pollution Control Standard 1-70 revised the pollution control standards established in 1954, making secondary treatment the minimum requirement for wastewater treatment plants and establishing equivalent treatment requirements for industry. From 1957 to 1965, $82,786,500 in federal aid was allocated to 638 projects in the Ohio Valley. The communities matched every federal dollar with $2.50 of local funds for a total of $282,966,000 spent on improving conditions. The majority of treatment works, both in place and under construction during this time, were equipped for secondary treatment. For 3 years before federal aid was offered, Pennsylvania provided incentives for smaller communities to upgrade their treatment by offering funds to communities upon compliance with standards. Although the population served by municipal facilities has increased greatly under these programs (Figure 11-6), increasingly high water quality criteria and limited funds have caused a sharp increase in population served by facilities classified as inadequate between 1965 and 1990.

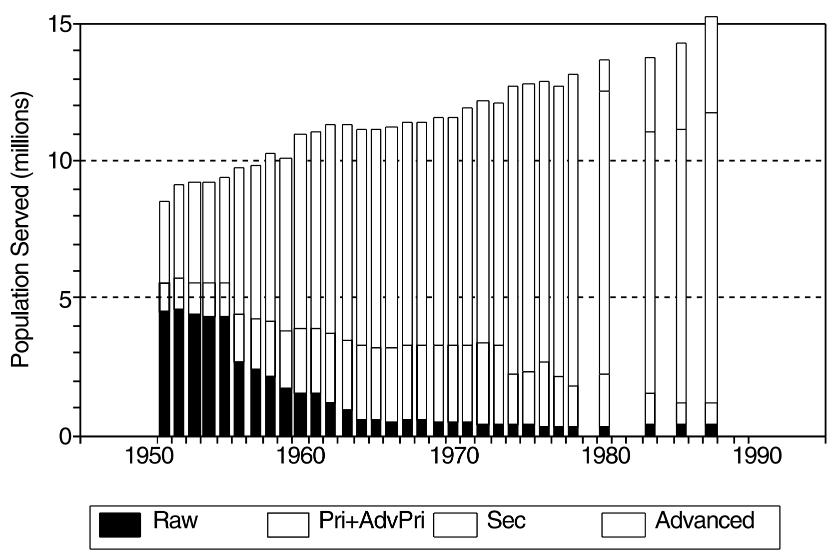


Figure 11-6

Long-term trends in population served by municipal wastewater treatment plants in the ORSANCO District.

Sources: ORSANCO, 1978, 1988.

Impact of Wastewater Treatment: Pollutant Loading and Water Quality Trends

Following the 1948 advances in cooperative management, water quality conditions in the Ohio River began to improve. A dramatic decrease occurred in the discharge of raw sewage from 1950 to 1963 (Figure 11-6). As a result of the stringent permit requirements on dischargers and improvements in wastewater treatment facilities implemented in the late 1960s and 1970s, even more advances have been made to upgrade wastewater treatment plants. Levels of BOD_5 effluent loading have decreased significantly, even as the influent loading continues to increase as population increases (Figure 11-7). Corresponding to the decreasing levels of pollutant loading is the increased amount of DO available to support aquatic organisms. Figure 11-8 shows the typical oxygen sag curve

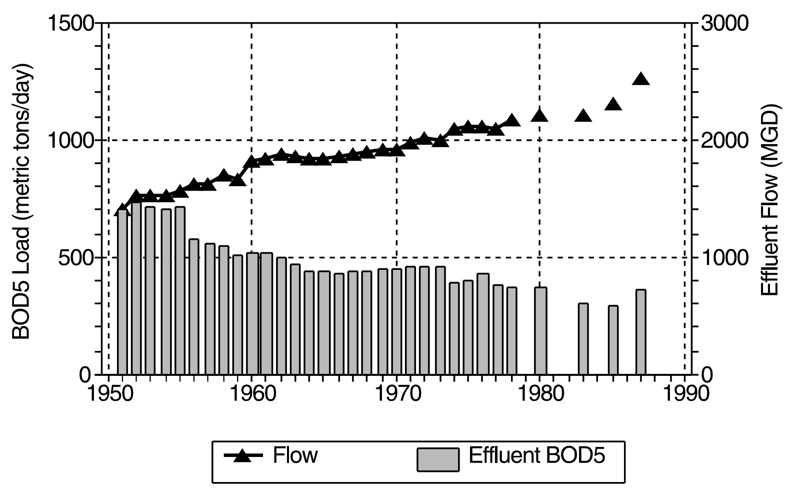


Figure 11-7

Long-term trends of wastewater flow, influent and effluent BOD_5 for the ORSANCO District. Data based on population served with 165 gallons per person per day, influent BOD_5 of 215 mg/L, and removal efficiencies of 36 percent (primary), 85 percent (secondary), and 95 percent (tertiary).

Sources: ORSANCO, 1978, 1987.

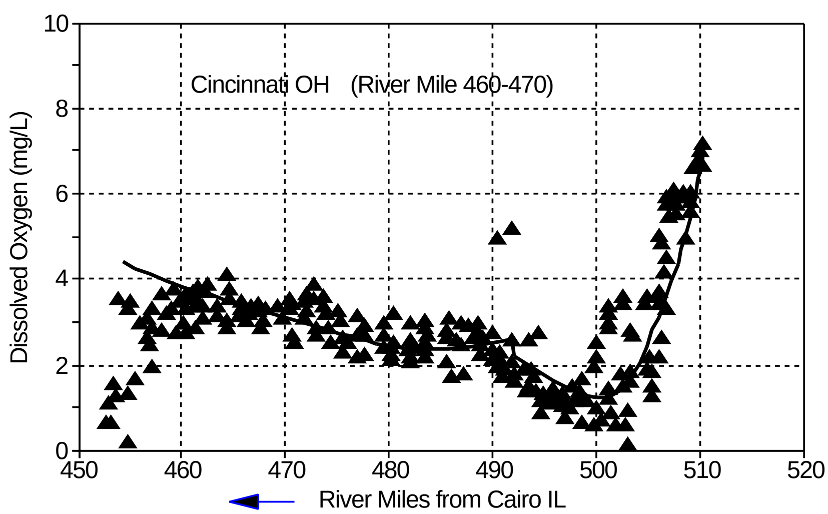


Figure 11-8

Spatial distribution of DO along the Ohio River downstream of Cincinnati: Oct.-Nov. 1963.

Source: HydroScience, 1969.

observed during the mid-1960s downstream from Cincinnati, Ohio, and indicates the sampling locations shown in Figures 11-9, 11-10, and 11-11. These data clearly illustrate an overall increase in oxygen following the 1972 CWA requirement for secondary treatment. A remarkable improvement in oxygen concentration occurs in the critical minimum occurring near North Bend/Fort Miami (milepoint 490) and at the pool formed by Markland Lock/Dam (milepoint 449-453). During the 1988 drought, for example, levels of DO continued to meet standards near Cincinnati and Louisville in contrast to the mid-1960s when consistent low-flow conditions resulted in DO concentrations below water quality standards (see Figures 11-9 and 11-13). Using the data compiled for trends in DO near Cincinnati (Figure 11-9) and Louisville (Figure 11-12), the mean summer 10th percentile level of DO significantly improved after the CWA (1986-1995) in comparison to conditions before the CWA (1961-1970) (Figure 11-13).

Water quality data collected since the 1950s indicate increased compliance with federal and ORSANCO criteria for DO, BOD_5, turbidity, pH, and many other water quality factors (Cleary, 1978; Wolman, 1971). ORSANCO (1979)

Figure 11-9

Long-term trends of DO near Cincinnati, Ohio (miles 460-470) (RF1-05090203002).

Source: USEPA (STORET).

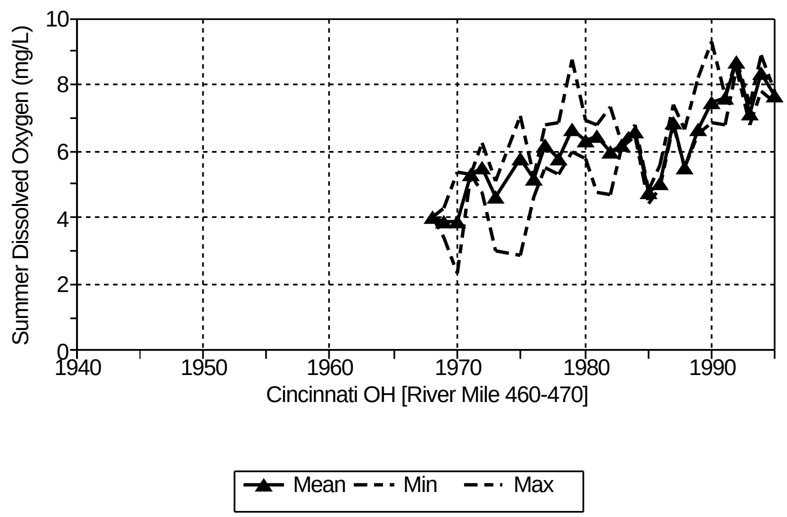
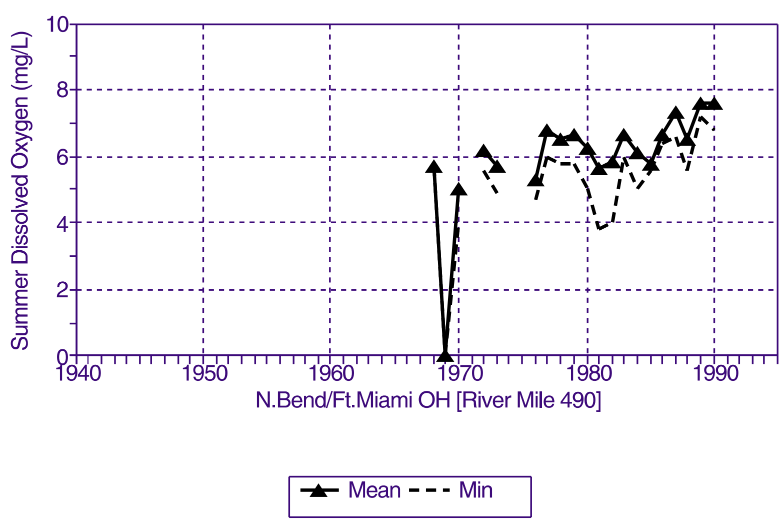


Figure 11-10

Long-term trends of DO at North Bend/Ft. Miami, Ohio (RF1-05090203012) (mile 490).

Source: USEPA (STORET).



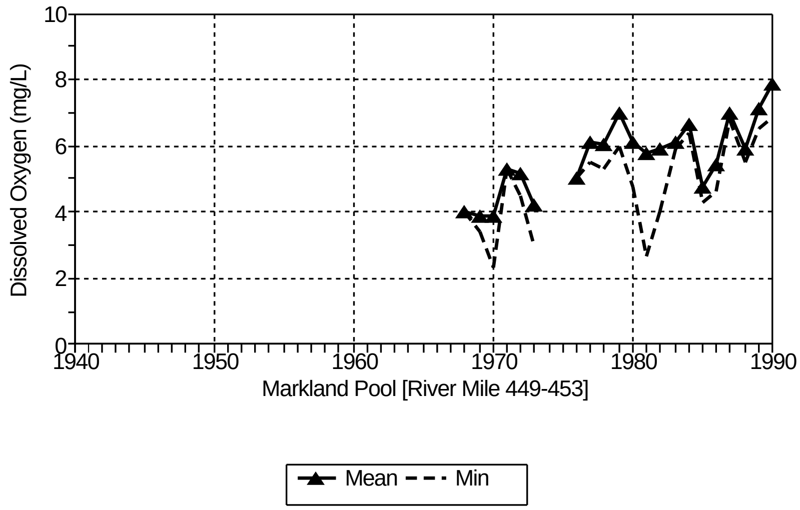


Figure 11-11

Long-term trends of DO at Markland Lock & Dam, Kentucky (miles 449-453) (RF1-05140101010).

Source: USEPA (STORET).

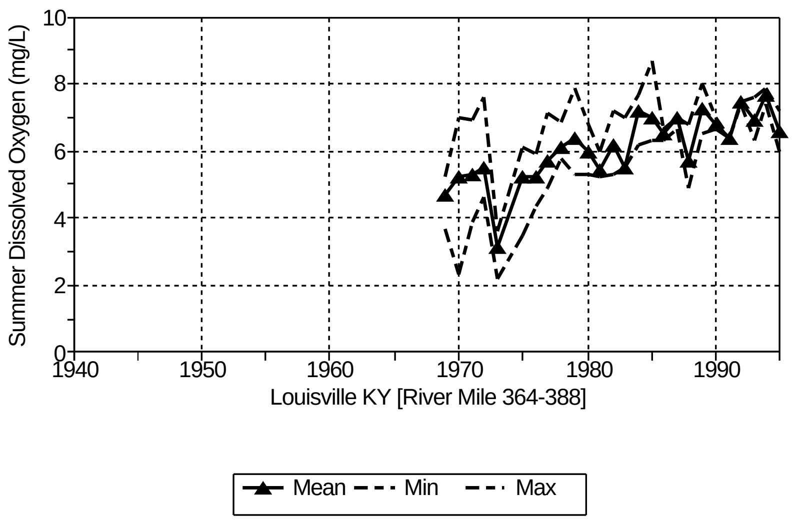


Figure 11-12

Long-term trends of DO at Louisville, Kentucky (miles 364-388) (RF1-0514010 1001).

Source: USEPA (STORET).

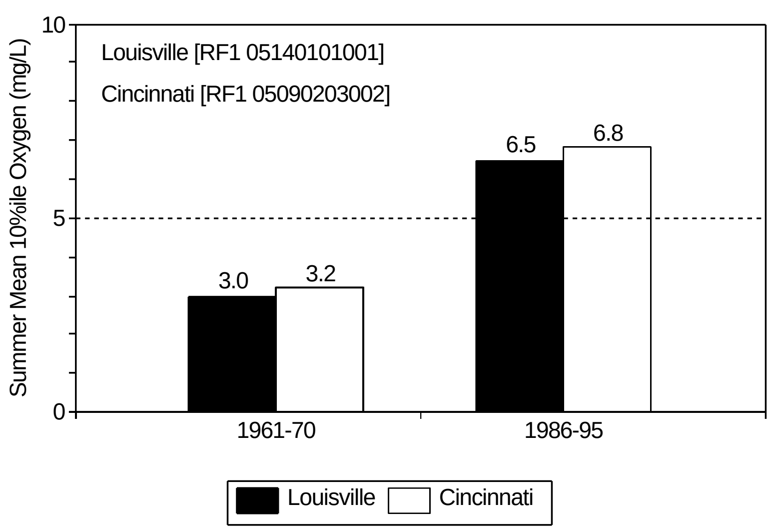


Figure 11-13

Before and after comparison of summer mean 10th percentile DO near Louisville, Kentucky (miles 364-368) and Cincinnati, Ohio (miles 460-470) during 1961-70 and 1986-95.

Source: USEPA (STORET).

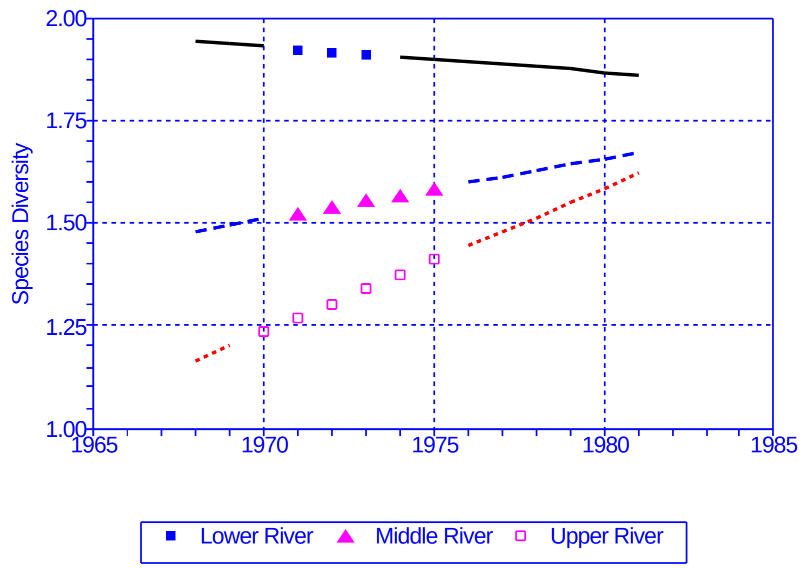


Figure 11-14

Long-term trends in fish diversity in the Ohio River.

Source: ORSANCO, 1982.

reports greater than 98.8 percent compliance for 15 out of 20 examined stream quality criteria. In 1990 ORSANCO published a statistical analysis of data resulting from water quality monitoring conducted over an 11-year period. Decreasing trends at individual sampling points were reported for a majority of the contaminants examined, and overall improving trends are indicated for total phosphorus, ammonia, nitrogen, copper, lead, and zinc. An indication of the improving water quality in the Ohio River is the marked increase in diversity of fish species with the greatest improvement seen in the upper reaches of the river (Figure 11-14). Increases are primarily noted in sport and commercially valuable species, which tend to be more pollution-sensitive than other fish species.

Impact of Wastewater Treatment: Recreational and Living Resources Trends

There is little long-term information on biological trends in the Ohio River (Pearson, 1992). Information on plants, invertebrates, and plankton is scarce or nonexistent. The only historical population data are for mussels, which were diverse and abundant in the 1800s but are less so now, even with water quality improvements in the river.

Data on fish populations in the middle section of the Ohio River have been collected since the 1950s and indicate that the populations have responded more positively than mussels to improved water quality (Figure 11-15). The first comprehensive fish population study on the Ohio River was done by ORSANCO in 1957, and the study has continued almost yearly since then. The study reports fish data according to section of the river—upper, middle, and lower. Louisville and Cincinnati are located in the middle section of the river. Changes in fish diversity since the study began have been most dramatic in the upper river, where a 40

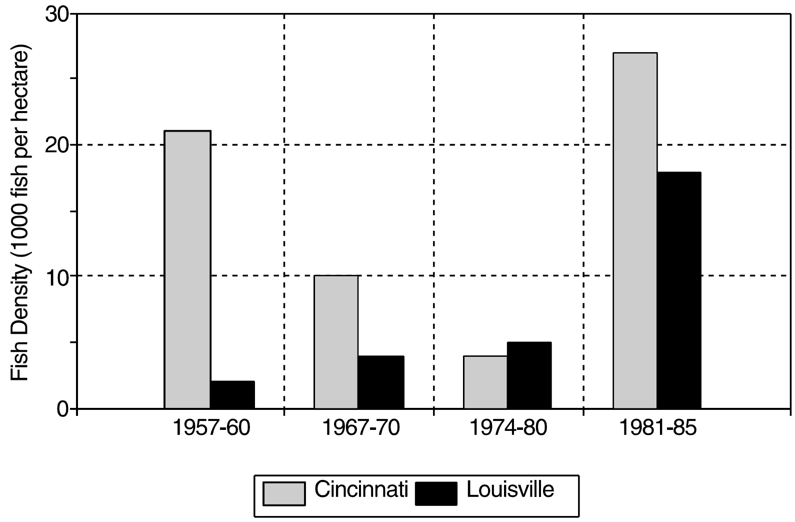


Figure 11-15

Long-term trends in Ohio River fish abundance at Cincinnati and Louisville.

Source: Pearson, 1992.

percent increase has been measured, but diversity has increased by 13 percent in the middle section as well (ORSANCO, 1982). Numbers of species and overall fish biomass are still increasing in the middle section of the river though they have not returned to their original levels. ORSANCO attributes the improvements to increased DO concentrations and pH, and to decreased levels of toxic materials in the river (ORSANCO, 1982).

Other studies also indicate continuing improvements in the quality of the Ohio River habitat. Studies by Geo-Marine conducted in the early 1980s near North Bend, Ohio (about 30 miles downstream of Cincinnati) found increasing numbers of species of larval fish, a life stage generally sensitive to DO levels (Geo-Marine, 1986). A trend toward a more even distribution of the numbers of individuals among the species captured was found as well, indicating improved habitat quality. The Ohio EPA has also conducted fish studies along the river. Their studies have found an Index of Biotic Integrity (IBI) near North Bend between 46 and 48 (OEPA, 1992). This is a fair to good rating, indicating habitats where tolerant and intolerant benthic species are both found. Benthos are particularly good indicators of long-term trends in water quality because the species are generally sedentary and have long life spans. For pollution studies, benthos are divided into three categories, and intolerant species are indicative of good water quality because of their inability to survive in, or intolerance of, low DO concentrations. Ohio EPA's sampling at North Bend in 1991 found a total of 23 species, with one intolerant species among them (Sanders, 1992a, 1992b; Plafkin et al., 1989).

Water quality improvements in the Ohio River have benefited both commercial and sport fisheries (Figure 11-15). Sportfishing, important recreationally and for tourism, began returning to the river in the mid-1980s. In 1982 the Bass Anglers Sportsman's Society held the Bass Champs Invitational at Cincinnati because of the reported bass catch in the river (ORSANCO, 1981). Such contests are now commonly held along the river.

Summary and Conclusions

Significant improvements have been accomplished throughout the Ohio River Basin through the combined efforts of federal, state, and local governments. The last half century has seen a reversal of the previous trend of river degradation. As of the mid-1990s nearly 94 percent of the Ohio River Basin's sewered population was served by at least secondary treatment. This accomplishment, on such a large scale, has shown what regional cooperation can achieve. The Ohio River now supports many uses that had previously been seriously impaired. Support of use for public water supply and aquatic habitat is maintained along the entire river. Sportfishing has returned, and the dramatic improvement in water quality is reflected in the increasing number of fishing tournaments along the river, including the 1983 Bass Masters Classic at Cincinnati.

Much progress has been made, but there is a recognizable need for further action. Water-based recreation continues to be impaired by high bacteria levels in the river. As of 1988 contact recreation was not supported on 59 percent of the river and was fully supported on only 6.5 percent of the river. Fish consumption advisories were still in effect for Kentucky, Ohio, Pennsylvania, and West Virginia in 1989 due to high levels of PCBs and chlordane found in fish tissues (ORSANCO 1989a). Certain metals, organic compounds, cyanide, phenol, copper, zinc, oxygen, and temperature also continue to pose a problem. ORSANCO is considering to address these and other stream quality impairments by addressing nonpoint source pollution controls (Norman, 1991), combined sewer overflow controls (Tennant et al., 1990), control of toxic chemicals (Vicory and Tennant, 1994), and control of ecological effects of hydropower development. Continued improvements are seen in monitoring, detection, and regulation, as well as treatment and spill response (Vicory and Tennant, 1993). The combination of present efforts with past achievements has put the Ohio River Basin on the road to recovery.

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